

EXHIBIT F



US010135682B2

(12) **United States Patent**
Ling et al.

(10) **Patent No.:** **US 10,135,682 B2**
(b4) **Date of Patent:** ***Nov. 20, 2018**

(54) **METHOD AND SYSTEM FOR SERVICE GROUP MANAGEMENT IN A CABLE NETWORK**

(71) Applicant: **Maxlinear, Inc.**, Carlsbad, CA (US)

(72) Inventors: **Curtis Ling**, Carlsbad, CA (US);
Sridhar Ramesh, Carlsbad, CA (US);
Timothy Gallagher, Carlsbad, CA (US)

(73) Assignee: **Maxlinear, Inc.**, Carlsbad, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/866,106**

(22) Filed: **Jan. 9, 2018**

(65) **Prior Publication Data**

US 2018/0131567 A1 May 10, 2018

Related U.S. Application Data

(63) Continuation of application No. 15/434,673, filed on Feb. 16, 2017, now Pat. No. 9,866,438, which is a (Continued)

(51) **Int. Cl.**

H04L 12/24 (2006.01)
H04L 1/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC **H04L 41/0823** (2013.01); **H04B 17/318** (2015.01); **H04L 1/0009** (2013.01); (Continued)

(58) **Field of Classification Search**

CPC . H04L 12/2801; H04L 1/0009; H04L 1/0026; H04L 27/2601; H04L 41/0823; H04L 43/08; H04L 43/12

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,563,918 A 10/1996 Waldschmidt
6,275,483 B1 8/2001 Papasakellariou
(Continued)

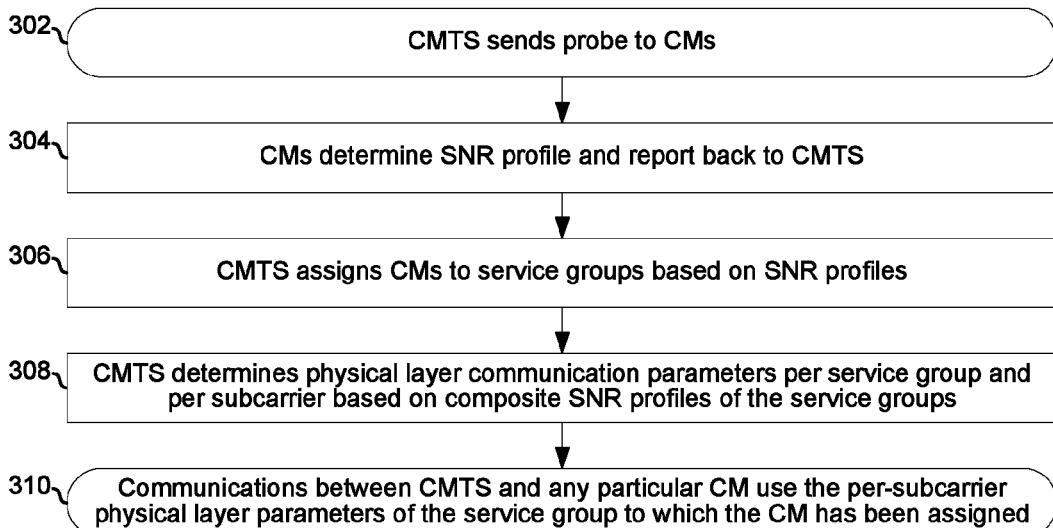
Primary Examiner — Dung B Huynh

(74) *Attorney, Agent, or Firm* — McAndrews, Held & Malloy, Ltd

(57) **ABSTRACT**

A cable modem termination system (CMTS) may determine, for a plurality of cable modems served by the CMTS, a corresponding plurality of SNR-related metrics. The CMTS may assign the modems among a plurality of service groups based on the SNR-related metrics. For any one of the modems, the CMTS may configure physical layer communication parameters to be used by the one of the modems based on a SNR-related metric of a service group to which the one of the modems is assigned. The physical layer communication parameters may include one or more of: transmit power, receive sensitivity, timeslot duration, modulation type, modulation order, forward error correction (FEC) type, and FEC code rate. The CMTS and the modems may communicate using orthogonal frequency division multiplexing (OFDM) over a plurality of subcarriers, and the physical layer communication parameters may be determined on a per-subcarrier basis.

18 Claims, 7 Drawing Sheets



US 10,135,682 B2

Page 2

Related U.S. Application Data

continuation of application No. 15/228,703, filed on Aug. 4, 2016, now Pat. No. 9,577,886, which is a continuation of application No. 13/948,444, filed on Jul. 23, 2013, now Pat. No. 9,419,858.

(60) Provisional application No. 61/674,742, filed on Jul. 23, 2012.

(51) Int. Cl.

H04B 17/318 (2015.01)
H04L 27/26 (2006.01)
H04L 12/28 (2006.01)
H04L 12/26 (2006.01)

(52) U.S. Cl.

CPC **H04L 1/0026** (2013.01); **H04L 12/2801** (2013.01); **H04L 27/2601** (2013.01); **H04L 27/2602** (2013.01); **H04L 43/08** (2013.01); **H04L 43/12** (2013.01)

(56)

References Cited

U.S. PATENT DOCUMENTS

6,421,327 B1	7/2002	Lundby	2003/0223481 A1	12/2003	Jones
6,560,225 B1	5/2003	Czajkowski	2003/0236071 A1	12/2003	Ito
6,757,522 B1	6/2004	Naegeli	2004/0085976 A1*	5/2004	Dale
6,891,858 B1	5/2005	Mahesh			H04B 7/18582
6,898,755 B1*	5/2005	Hou			370/411
			2004/0218568 A1	11/2004	Goodall
			2005/0097617 A1	5/2005	Currivan
			2005/0122996 A1	6/2005	Azenkot
			2005/0135253 A1	6/2005	Cai et al.
			2005/0185824 A1	8/2005	Chen
			2005/0213579 A1	9/2005	Iyer
			2006/0008020 A1	1/2006	Blankenship
			2006/0067278 A1*	3/2006	Li
					H04B 1/707
					370/335
			2006/0126505 A1*	6/2006	Denney
					H04J 3/1694
					370/229
			2007/0098007 A1	5/2007	Prodan
			2007/0202904 A1	8/2007	Cheng
			2007/0253388 A1	11/2007	Pietraski
			2009/0016420 A1	1/2009	Kwak
			2009/0040942 A1	2/2009	Yang
			2009/0215403 A1	8/2009	Currivan
			2009/0219856 A1*	9/2009	Richardson
					H04W 72/044
					370/328
			2010/0002575 A1	1/2010	Eichinger
			2010/0100919 A1	4/2010	Hsue
			2010/0154017 A1*	6/2010	An
					H04L 12/2801
					725/111
			2010/0172316 A1	7/2010	Hwang
			2011/0051607 A1	3/2011	Begen
			2011/0188852 A1	8/2011	Stodola
			2011/0306380 A1	12/2011	Zavadsky
			2012/0269242 A1	10/2012	Prodan
			2013/0021931 A1	1/2013	Kim
			2013/0024753 A1	1/2013	Masuda
			2013/0100843 A1	4/2013	Croak
			2013/0107921 A1	5/2013	Prodan
			2013/0114480 A1	5/2013	Chapman
			2013/0170528 A1*	7/2013	Pantelias
					H04L 12/2801
					375/222
			2013/0227373 A1	8/2013	Shen
			2013/0266310 A1	10/2013	Fox
			2014/0022926 A1	1/2014	Ling
			2014/0133330 A1	5/2014	Chapman
			2014/0169431 A1	6/2014	Arambepola
			2014/0286203 A1	9/2014	Jindal
			2014/0301237 A1	10/2014	Yi
			2015/0071161 A1	3/2015	Salhab
			2015/0288498 A1	10/2015	Kliger

* cited by examiner

U.S. Patent

Nov. 20, 2018

Sheet 1 of 7

US 10,135,682 B2

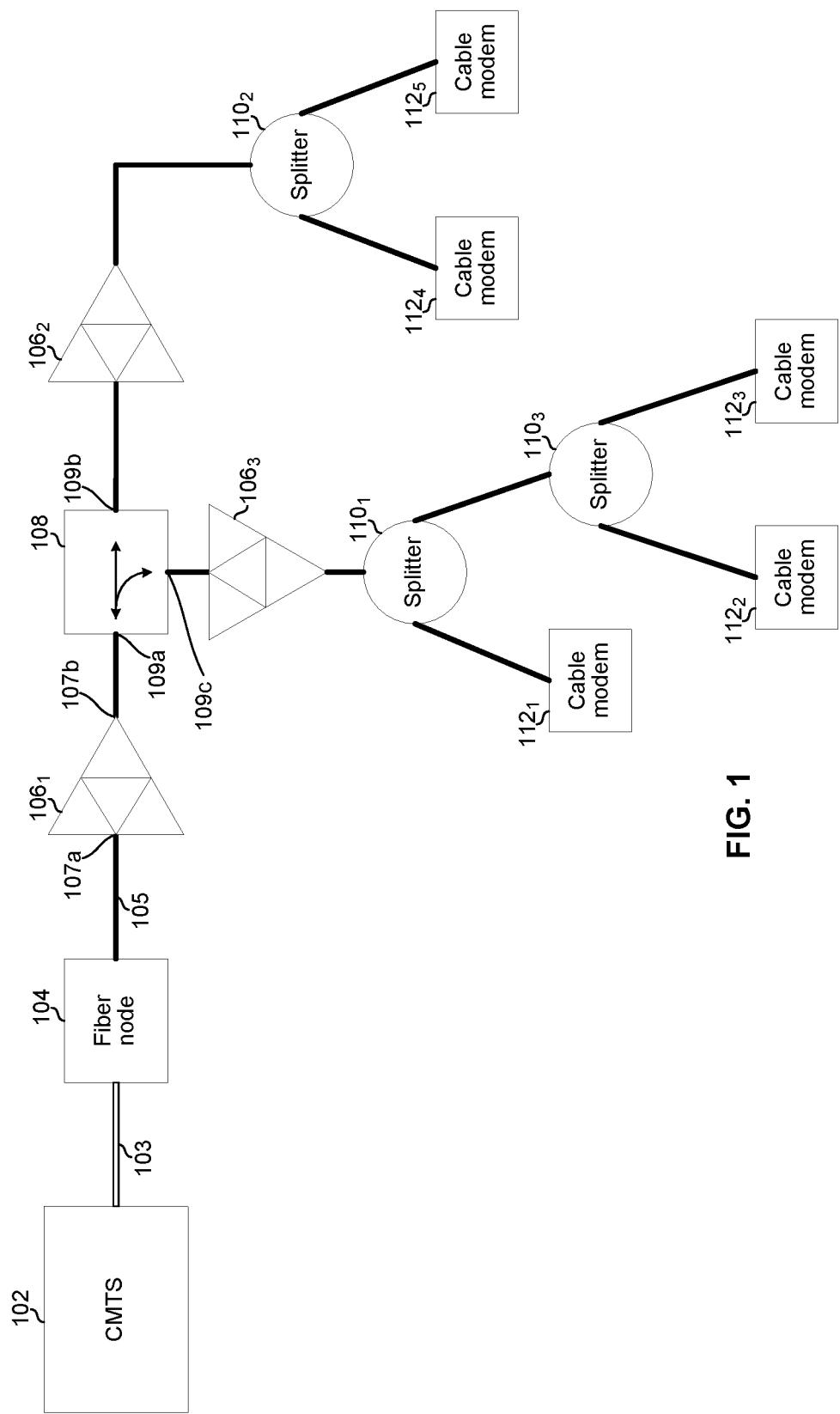


FIG. 1

U.S. Patent

Nov. 20, 2018

Sheet 2 of 7

US 10,135,682 B2

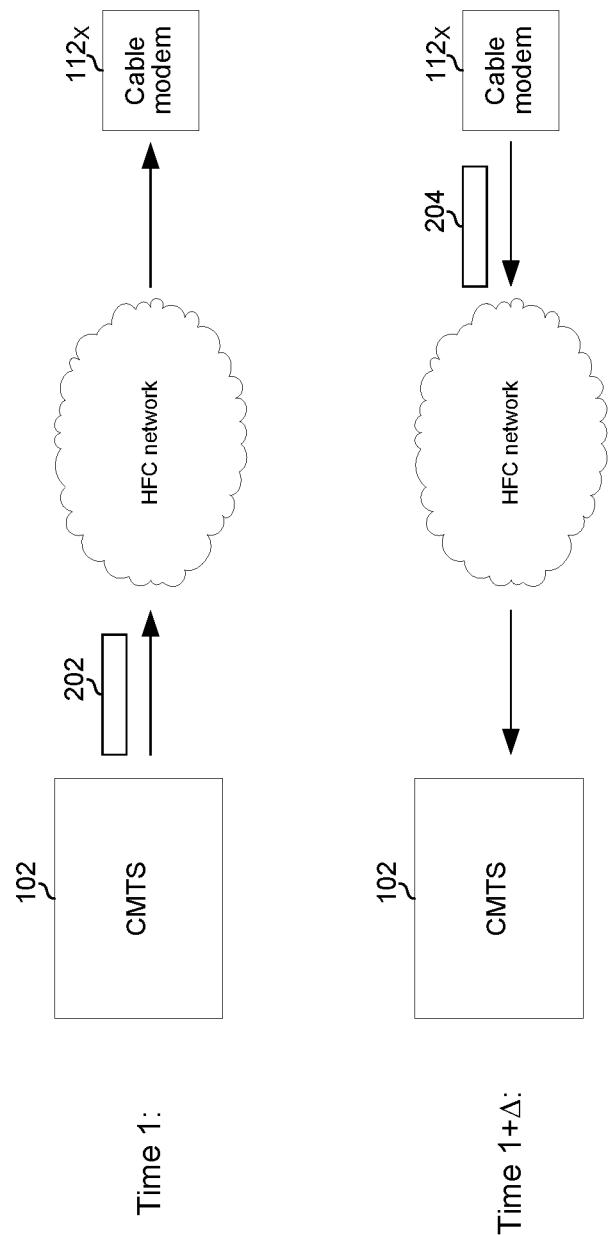


FIG. 2A

U.S. Patent

Nov. 20, 2018

Sheet 3 of 7

US 10,135,682 B2

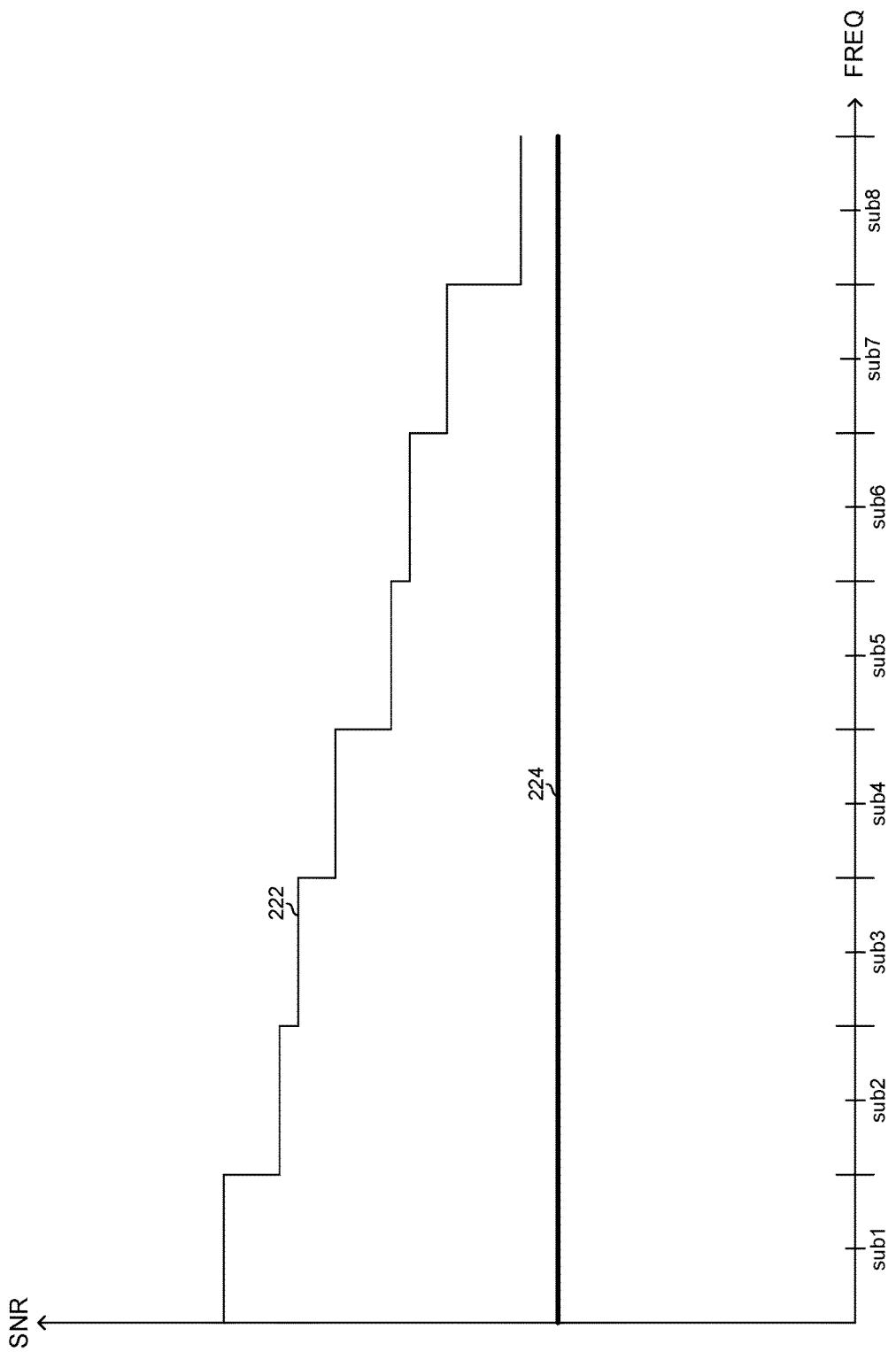


FIG. 2B

U.S. Patent

Nov. 20, 2018

Sheet 4 of 7

US 10,135,682 B2

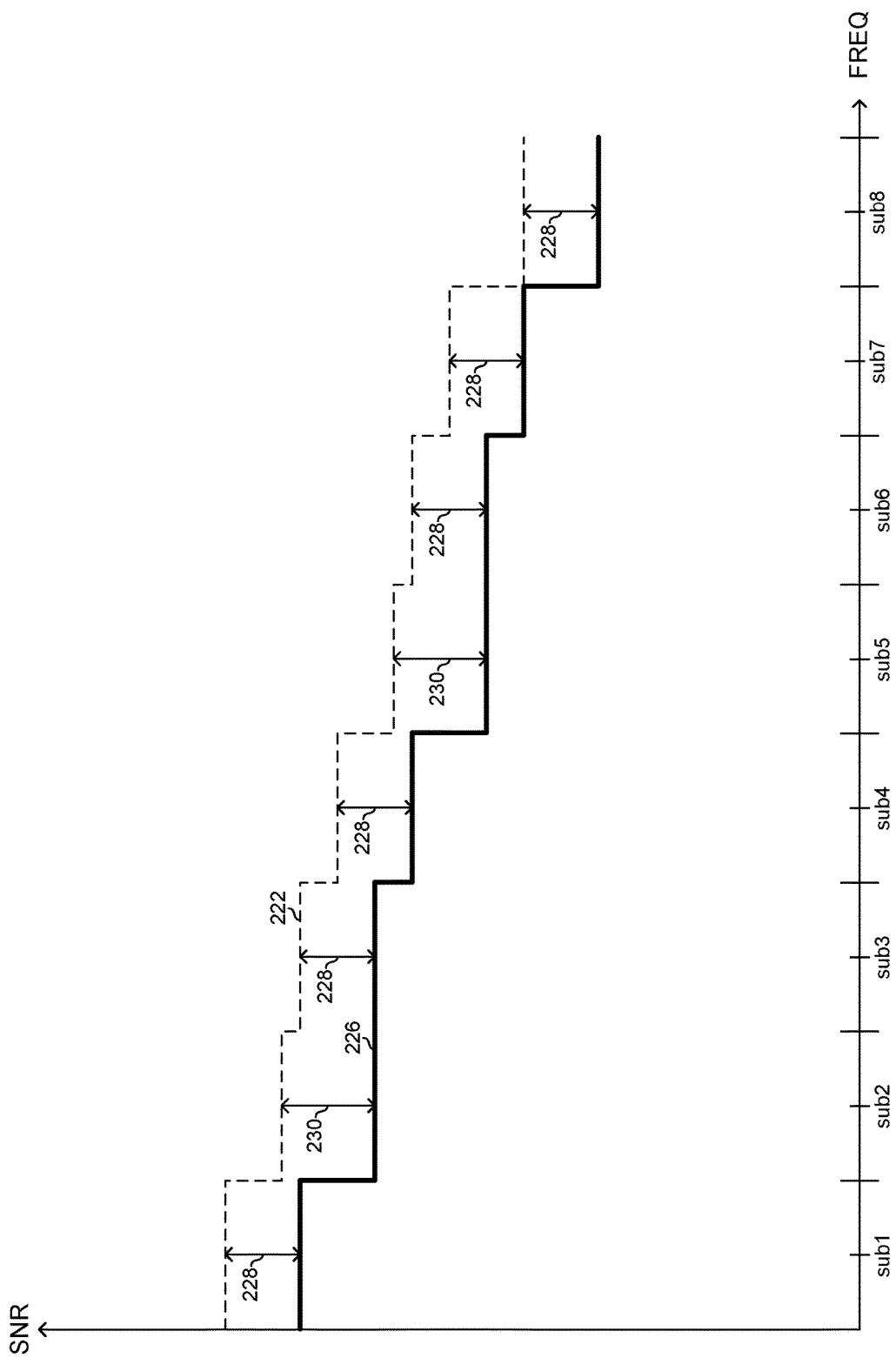


FIG. 2C

U.S. Patent

Nov. 20, 2018

Sheet 5 of 7

US 10,135,682 B2

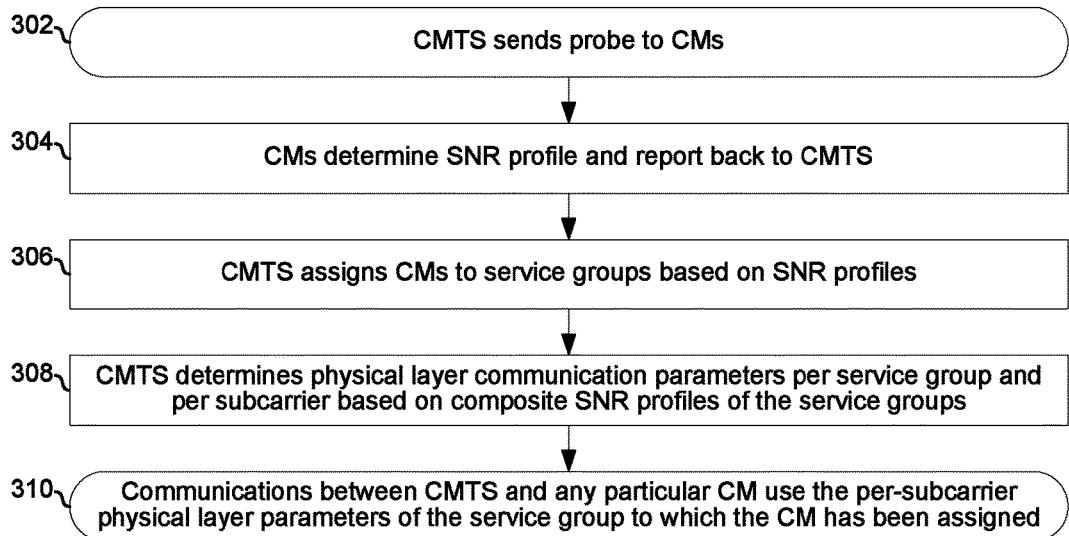


FIG. 3A

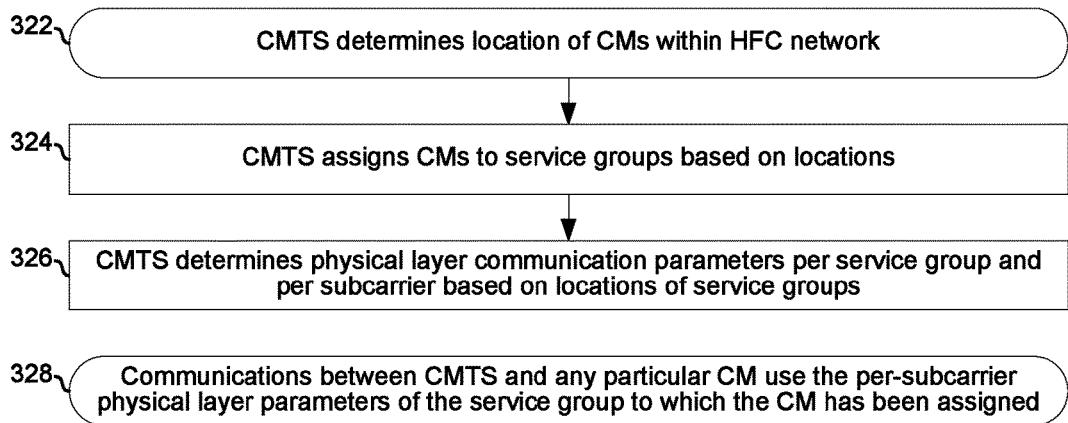


FIG. 3B

U.S. Patent

Nov. 20, 2018

Sheet 6 of 7

US 10,135,682 B2

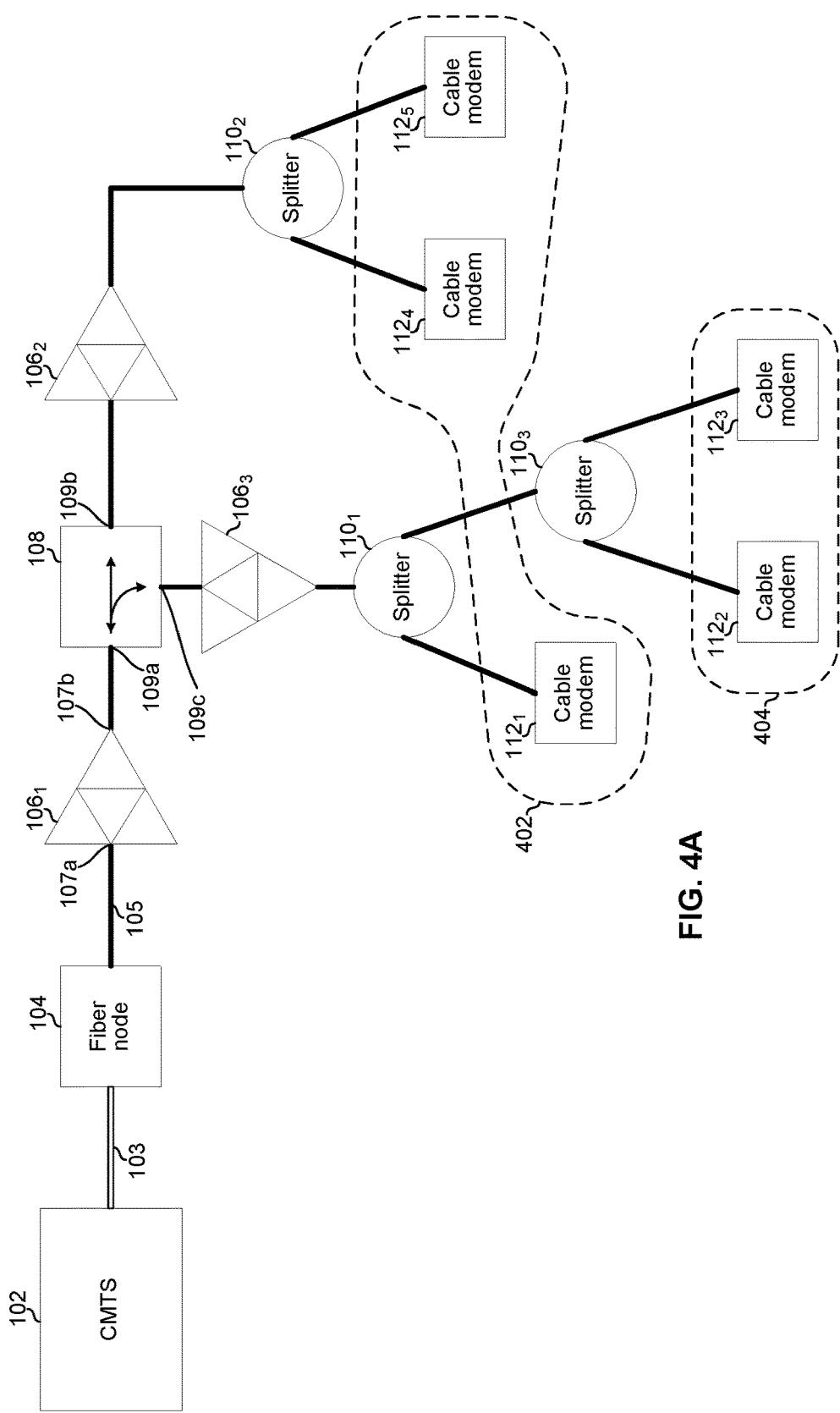


FIG. 4A

U.S. Patent

Nov. 20, 2018

Sheet 7 of 7

US 10,135,682 B2

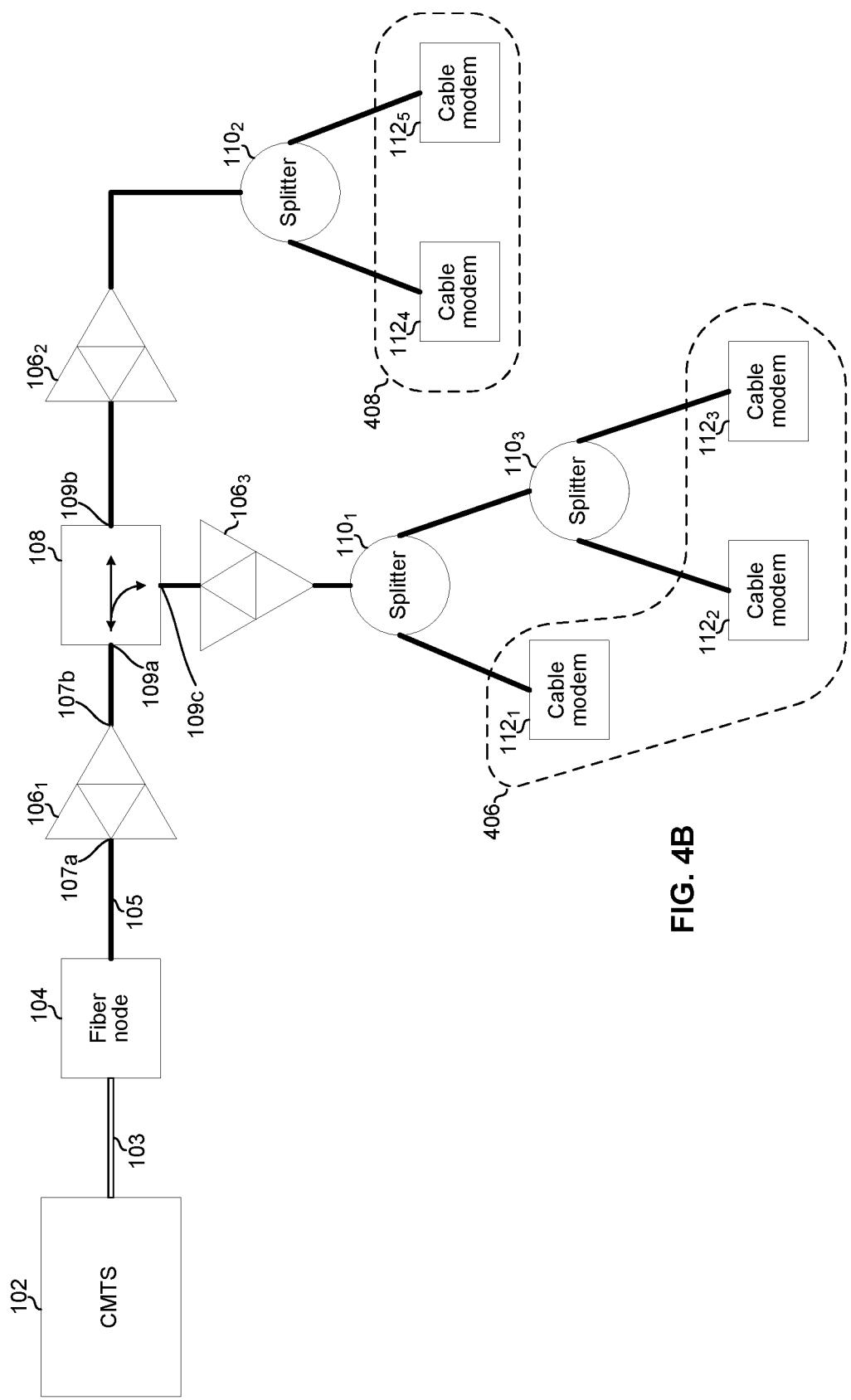


FIG. 4B

US 10,135,682 B2

1

**METHOD AND SYSTEM FOR SERVICE
GROUP MANAGEMENT IN A CABLE
NETWORK**

PRIORITY CLAIM

This patent application is a continuation of U.S. patent application Ser. No. 15/434,673 filed on Feb. 16, 2017, which is a continuation of U.S. patent application Ser. No. 15/228,703 filed on Aug. 4, 2016, now U.S. Pat. No. 9,577,886, which is a continuation of U.S. patent application Ser. No. 13/948,444 filed on Jul. 23, 2013, now U.S. Pat. No. 9,419,858, which makes reference to, claims priority to and claims benefit from U.S. Provisional Patent Application Ser. No. 61/674,742 titled “Method and System for Service Group Management in a Cable Television Network” and filed on Jul. 23, 2012.

The entirety of each of the above-mentioned applications is hereby incorporated herein by reference.

INCORPORATION BY REFERENCE

This application also makes reference to:

U.S. patent application Ser. No. 13/553,328 titled “Method and System for Client-Side Message Handling in a Low-Power Wide Area Network,” and filed on Jul. 19, 2012;

U.S. patent application Ser. No. 13/485,034 titled “Method and System for Server-Side Message Handling in a Low-Power Wide Area Network,” and filed on May 31, 2012;

U.S. patent application Ser. No. 13/553,175 titled “Method and System for a Low-Power Client in a Wide Area Network,” and filed on Jul. 19, 2012;

U.S. patent application Ser. No. 13/553,195 titled “Method and System for Server-Side Handling of a Low-Power Client in a Wide Area Network,” and filed on Jul. 19, 2012;

U.S. patent application Ser. No. 13/948,401 titled “Method and System for a High Capacity Cable Network,” and filed on the same date as this application; and

U.S. patent application Ser. No. 13/948,417 titled “Method and System for Noise Suppression in a Cable Network,” and filed on the same date as this application.

The entirety of each of the above-mentioned applications is hereby incorporated herein by reference.

FIELD OF THE INVENTION

Certain embodiments of the invention relate to cable television networks. More specifically, certain embodiments of the invention relate to a method and system for service group management in a cable television network.

BACKGROUND OF THE INVENTION

Convention cable television networks can be inefficient and have insufficient capacity. Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with some aspects of the present invention as set forth in the remainder of the present application with reference to the drawings.

BRIEF SUMMARY OF THE INVENTION

A system and/or method is provided for service group management in a cable television network, substantially as

2

shown in and/or described in connection with at least one of the figures, as set forth more completely in the claims.

These and other advantages, aspects and novel features of the present invention, as well as details of an illustrated embodiment thereof, will be more fully understood from the following description and drawings.

**BRIEF DESCRIPTION OF SEVERAL VIEWS OF
THE DRAWINGS**

FIG. 1 is a diagram of an example cable/DOCSIS network.

FIG. 2A depicts an example method of determining locations of CMs within the HFC network.

FIGS. 2B and 2C depict signal-to-noise ratio (SNR) versus frequency profiles for an example cable/DOCSIS network.

FIG. 3A is a flowchart illustrating an example process for configuring a cable/DOCSIS HFC network based on measured performance metrics.

FIG. 3B is a flowchart illustrating an example process for configuring a cable/DOCSIS HFC network based on location of CMs within the network.

FIGS. 4A and 4B illustrate the network of FIG. 1, with different groupings of CMs based on one or both of: measured performance metric(s) and location within the HFC network.

**DETAILED DESCRIPTION OF THE
INVENTION**

As utilized herein the terms “circuits” and “circuitry” refer to physical electronic components (i.e. hardware) and any software and/or firmware (“code”) which may configure the hardware, be executed by the hardware, and/or otherwise be associated with the hardware. As used herein, for example, a particular processor and memory may comprise a first “circuit” when executing a first one or more lines of code and may comprise a second “circuit” when executing a second one or more lines of code. As utilized herein, “and/or” means any one or more of the items in the list joined by “and/or”. As an example, “x and/or y” means any element of the three-element set $\{(x), (y), (x, y)\}$. As another example, “x, y, and/or z” means any element of the seven-element set $\{(x), (y), (z), (x, y), (x, z), (y, z), (x, y, z)\}$. As utilized herein, the term “exemplary” means serving as a non-limiting example, instance, or illustration. As utilized herein, the terms “e.g.,” and “for example” set off lists of one or more non-limiting examples, instances, or illustrations. As utilized herein, circuitry is “operable” to perform a function whenever the circuitry comprises the necessary hardware and code (if any is necessary) to perform the function, regardless of whether performance of the function is disabled, or not enabled, by some user-configurable setting.

FIG. 1 is a diagram of an example cable/DOCSIS network. The example network comprises a cable modem termination system (CMTS) 102, a fiber node 104, amplifiers 106₁-106₃, a directional coupler 108, splitters 110₁-110₃, and cable modems (CMs) 112₁-112₅.

The CMTS 102 may comprise circuitry operable to manage connections to the CMs 112₁-112₅. This may include, for example: participating in ranging operations to determine physical layer parameters used for communications between the CMTS 102 and CMs 112₁-112₅; forwarding of dynamic host configuration protocol (DHCP) messages between a DHCP server and the CMs 112₁-112₅; forwarding of time of

US 10,135,682 B2

3

day messages between a time of day server and the CMs 112_1 - 112_5 ; directing traffic between the CMs 112_1 - 112_5 other network devices (e.g., Ethernet interfaces of the CMTS 102 may face the Internet, Optical RF interfaces of the CMTS 102 may face the CMs, and the CMTS may direct traffic between and among the Ethernet and Optical RF interfaces); and managing registration of the CMs 112_1 - 112_5 to grant the cable modems network (e.g., Internet) access. The registration process for a CM 112_X (X between 1 and 5 for the example network of FIG. 1) may comprise the CM 112 sending a registration request along with its configuration settings, and the CMTS 102 accepting or rejecting the cable modem based on the configuration settings. The registration process may additionally comprise an exchange of security keys, certificates, or other authentication information.

The fiber node 104 may comprise circuitry operable to convert between optical signals conveyed via the fiber optic cable 103 and electrical signals conveyed via coaxial cable 105 .

Each of the amplifiers 106_1 - 106_3 may comprise a bidirectional amplifier which may amplify downstream signals and upstream signals, where downstream signals are input via upstream interface $107a$ and output via downstream interface $107b$, and upstream signals are input via downstream interface $107b$ and output via upstream interface $107a$. The amplifiers 106_1 , which amplifies signals along the main coaxial “trunk” may be referred to as a “trunk amplifier.” The amplifiers 106_2 and 106_3 which amplify signals along “branches” split off from the trunk may be referred to as “branch” or “distribution” amplifiers.

The directional coupler 108 may comprise circuitry operable to direct downstream traffic incident on interface $109a$ onto interfaces $109b$ and $109c$, and to direct upstream traffic incident on interfaces $109b$ and $109c$ onto interface $109a$. The directional coupler 108 may be a passive device.

Each of the splitters 110_1 - 110_3 may comprise circuitry operable to output signals incident on each of its interfaces onto each of its other interfaces. Each of the splitters 110_1 - 110_3 may be a passive device.

Each of the cable modems (CMs) 112_1 - 112_5 may comprise circuitry operable to communicate with, and be managed by, the CMTS 102 in accordance with one or more standards (e.g., DOCSIS). Each of the CMs 112_1 - 112_5 may reside at the premises of a cable subscriber.

The components (including, fiber optic cables, coaxial cables, amplifiers, directional couplers, splitters, and/or other devices) between the CMTS and the CMs may be referred to as a hybrid fiber coaxial (HFC) network. Any of the amplifiers, directional coupler, and splitters may be referred to generically as a coupling device.

FIG. 2A depicts an example method of determining locations of CMs within the HFC network. As shown in FIG. 2A, to determine one or more measured performance metric(s) (e.g., an SNR-related metric such as SNR at a particular frequency or SNR over a range of frequencies (an SNR profile), noise levels, strength of desired signals, and/or the like) for any particular CM 112_X , the CMTS 102 may transmit, at time 1, a message 202 that is destined (unicast, multicast, or broadcast) for the CM 112_X and that functions as a probe to enable determination of the metric(s) for the CM 112_X . The message 202 may be sent on multiple channels spanning multiple frequencies. Similarly, where OFDM is used for communications between the CMTS 102 and the CM 112_X , the message 202 may be transmitted on each subcarrier, or may be sent on a subset of subcarriers and

4

then interpolation may be used for determining the SNR of subcarriers on which the message 202 was not sent.

The message 202 may be transmitted with such encoding, modulation, and transmit power such that even a CM 112_X with a worst-case performance metric(s) can receive the message and accurately measure the metric(s). In this regard, FIG. 2B shows a SNR versus frequency graph for an example HFC network that uses eight channels/subcarriers. The line 222 in FIG. 2B represents a composite worst-case SNR profile for one or more CM(s) in the HFC network to which the message 202 is destined. For example, line 222 may be a SNR profile for a single CM 112_X to which the message 202 is to be unicast. As another example, the line 222 may be a composite worst-case SNR profile for a plurality of CMs 112 of a particular service group to which the message 202 is to be multicast. As another example, the line 222 may be a composite worst-case SNR profile for all CMs of an HFC network handled by the CMTS 102 to which the message 202 is to be broadcast. The message 202 may be transmitted such that the minimum SNR needed to receive and accurately measure the SNR profile is below the line 222 (e.g., SNR needed for receiving the message 202 may be the line 224).

Upon receipt of the message 202 , a CM 112_X may measure, over the channels/subbands on which the message was sent, one or more metrics (e.g., SNR versus frequency profile) for the transmission 202 . The CM 112_X may then report the metrics(s) back to the CMTS 102 via a message 204 . In an example implementation, the message 202 may contain information about when and/or how the CM(s) are supposed to report their metric(s) (e.g., SNR profiles) back to the CMTS 102 . In this regard, the message 202 may contain information that is the same as and/or analogous to what may be found in a MAP, UCD, and/or other MAC management message defined in a DOCSIS standard. Accordingly, the message 202 may have specified a format of the message 204 and that the message 204 is to be transmitted at time $T+\square$.

Once the metric(s) of one or more CMs are known to the CMTS 102 , physical layer communication parameters to be used for communications between the CMTS 102 and the CMs 112 may be determined based on the metric(s). In this regard, physical layer communication parameters may be determined per-CM based on each CM's respective metric(s) (e.g., each CM's SNR profile), per-service-group based on a composite metric(s) of the CM(s) assigned to that service group (e.g., composite SNR profile for the CM(s) of that service group), per physical region of the HFC network based on a composite metric of the CMs located in that physical region (e.g., composite SNR profile for the CM(s) in that physical region), and/or the like. Furthermore, once the metric(s) of a CM 112_X is determined, the CMTS 102 may assign that CM 112_X to one or more service groups based on its metric(s), as, for example, described below with reference to FIG. 4A. Example physical layer parameters include: encoding parameters, modulation parameters, transmit power, receive sensitivity, timeslot duration, channel(s) or subcarrier(s) on which to listen, channel(s) or subcarrier(s) on which to transmit, and/or the like. Example encoding parameters include: type of forward error correction (FEC) to be used (e.g., Reed-Solomon, LDPC, etc.), FEC block size, FEC code rate, etc. Example modulation parameters include: type of modulation (e.g., frequency shift keying (FSK), phase shift keying (PSK), quadrature amplitude modulation (QAM), etc.), modulation depth, modulation order, etc.

US 10,135,682 B2

5

In an example implementation, the transmission of messages **202**, the calculation of metrics, such as SNR profile, by the CM(s), the transmission **204**, and subsequent configuration of physical layer parameters based on the metric(s) may take place in parallel with other operations performed during the registration/ranging process.

Referring now to FIG. 2C, there is again shown the line **222** which represents the applicable SNR profile (e.g., an individual SNR profile if configuring physical layer parameters per CM, a composite SNR profile for a service group if configuring physical layer parameters per service group, or a composite SNR profile for a particular physical region). Also shown is a line **226** corresponding to SNR utilization for communications with the CM(s) associated with the profile **222**. Assuming the distance **228** is the minimum desired headroom, then the physical layer communication parameters resulting in line **226** are nearly optimal in the sense that there is minimal headroom on each of channels/subbands **1, 3, 4, 6, 7, 8**, and only slightly more than minimal headroom on channels/subbands **2** and **5**.

Physical layer parameters may be configured/coordinated using upstream and/or downstream MAP messages, upstream channel descriptors (UCDs), other MAC management messages defined in DOCSIS protocols, and/or purpose-specific messages tailored to configuring the parameters based on measured performance metrics such as SNR profiles as described in this disclosure.

FIG. 3A is a flowchart illustrating an example process for configuring a cable/DOCSIS HFC network based on SNR profiles. For clarity of illustration the process is described with reference to the network of FIG. 1 and the messages of FIG. 2A. The process begins with block **302** in which the CMTS **102** sends one or more probe messages **202** to the CMs **112₁-112₅**. In block **304**, each of the CMs **112₁-112₅** determines its respective SNR profile based on a received one of the messages **202**, and reports the SNR profile back to the CMTS **102** in the form of a message **204**. In block **306**, the CMTS **102** assigns the CMs to service groups based on the SNR profiles.

In block **308**, physical layer communication parameters are determined per service group and per channel/subcarrier. For example, for any particular service group, the modulation order and FEC code rate to be used on a particular subcarrier may be determined based on the worst case SNR for that subcarrier among the CMs in that particular service group. Thus, it can be seen that grouping CMs based on SNR profiles may enable configuring physical layer communications parameters to such that one or more communication parameters (throughput, reliability, etc.) is optimal, or near-optimal, for all of the CMs in the service group. For example, without such grouping by SNR profile, one CM in a particular service group may have substantially lower SNR on one or more channels/subcarriers. As a result, all CMs in that particular service group may be forced to use physical layer parameters supported by this “lowest common denominator” CM. This may result in a lot of wasted capacity for the remaining CMs.

To illustrate with a specific example: assume that CMs **112₁**, **112₄**, and **112₅** of FIG. 1 have sufficient SNR on channel z to support 64-QAM on channel z, but that CMs **112₂** and **112₃** only have sufficient SNR on channel z to support 16-QAM. If **112₁** is assigned to the same service group as **112₂** or **112₃**, then **112₁** may be forced to use 16-QAM on channel z. Conversely, if **112₁**, **112₄**, and **112₅** are assigned to a first service group and **112₂** and **112₃** are assigned to a second service group, then the first service group consisting of **112₁**, **112₄**, and **112₅** can use 64-QAM

6

on channel z while the second service group consisting of **112₂** and **112₃** uses 16-QAM on channel z.

In block **310**, communications between the CMTS **102** and any particular service group use the per-service-group and per-subcarrier/channel physical layer parameters determined in block **308**.

FIG. 3B is a flowchart illustrating an example process for configuring a cable/DOCSIS HFC network based on location of CMs within the network. For clarity of illustration, 10 and as a non-limiting example, the process is described with reference to the network of FIG. 1 and the messages of FIG. 2B. The process begins with block **322** in which the CMTS **102** determines a location of each of the CMs **112₁-112₅** in the network. Location of a CM **112_x** may be characterized in 15 a variety of ways including, for example: total distance of fiber and/or coaxial cable between the CMTS **102** and the CM **112_x**, total attenuation between the CMTS **102** and the CM **112_x**, how many coupling elements (amplifiers, splitters, 20 directional couplers, etc.) are between the CMTS **102** and the CM **112_x**, GPS coordinates, and street address. In block **324**, the CMTS **102** assigns the CMs **112₁-112₅** to service groups based on their determined locations. Blocks **326** and **328** are substantially similar to blocks **308** and **310**, respectively, of FIG. 3A.

The locations of the CMs **112₁-112₅** may be determined by, for example, transmitting sounding signals into the network. In order to characterize the channel with more precision, the channel sounding signal may be sent repeatedly over an interval of time and the CMs may average 30 multiple measurements over the time interval until they can resolve identifying characteristics in the signal which indicate, for example, how many branch amplifiers and/or other coupling elements that the signal traveled through to reach the CM. In another example implementation, the CMTS may communicate with a server that stores subscriber information that associates the CMs with their geographic location (e.g., street address).

While FIGS. 3A and 3B depict SNR profiles and location 40 as two separate bases on which to assign CMs to service groups, the two may be used in combination.

FIGS. 4A and 4B illustrate the network of FIG. 1, with different groupings of CMs based on one or both of: measured performance metric(s) and location within the HFC 45 network.

In the example of FIG. 4A, CMs **112₁**, **112₄**, and **112₅** are assigned to service group **402** and CMs **112₂** and **112₃** are assigned to service group **404**. The assignment of FIG. 4A may result from, for example, assigning CMs based on the number of coupling elements between the CMTS **102** and the CMs—four each for CMs **112₁**, **112₄**, and **112₅**; five each for CMs **112₂** and **112₃**. The number of coupling elements may be determined based on, for example, measured performance metrics (e.g., SNR profile) of the CMs and/or address or GPS information associated with the CMs. Alternatively, the assignment of FIG. 3A may result from, for example, assigning the CMs to service groups based directly on their respective measured performance metric(s) (e.g., the extra device in the path between CMTS **102** and CMs **112₂** and **112₃** may cause CMs **112₂** and **112₃** to have significantly poorer SNR).

In the example of FIG. 4B, CMs **112₁**, **112₂**, and **112₃** are assigned to service group **406** and CMs **112₄** and **112₅** are assigned to service group **408**. The assignment of FIG. 4B 65 may result from, for example, assigning CMs based on which trunk amplifiers are downstream of the CMs. Alternatively, the assignment of FIG. 3A may result from, for

US 10,135,682 B2

7

example, assigning the CMs to service groups based directly on their respective measured performance metric(s) (e.g., the distance between CMTS 102 and CMs 112₄ and 112₅ may be substantially greater than the distance between the CMTS 102 and the CMs 112₁, 112₂, and 112₃, thus resulting in poorer SNR in CMs 112₄ and 112₅).

Grouping CMs according to which trunk or distribution amplifiers are upstream of them may enable duty cycling power branch and/or distribution amplifiers. For example, when a CM in service group 406 is the talker, the upstream path through amplifier 106₂ may be disabled such that noise from group 408 does not interfere with transmissions from the talker of service group 406. Grouping CMs according to which trunk or distribution amplifier(s) serve(s) them may enable using more efficient physical layer parameters. For example, where there is a relatively long distance of cable between amplifier 106₁ and 106₂ but relatively short distance of cable between amplifiers 106₁ and 106₃, grouping the CMs by geography/distance to the CMTS may enable a lower transmit power to be used by the CMTS 102 when talking to service group 406 as compared to when talking to service group 408.

Other embodiments of the invention may provide a non-transitory computer readable medium and/or storage medium, and/or a non-transitory machine readable medium and/or storage medium, having stored thereon, a machine code and/or a computer program having at least one code section executable by a machine and/or a computer, thereby causing the machine and/or computer to perform processes described.

Accordingly, the present invention may be realized in hardware, software, or a combination of hardware and software. The present invention may be realized in a centralized fashion in at least one computing system, or in a distributed fashion where different elements are spread across several interconnected computing systems. Any kind of computing system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software may be a general-purpose computing system with a program or other code that, when being loaded and executed, controls the computing system such that it carries out the methods described herein. Another typical implementation may comprise an application specific integrated circuit or chip.

The present invention may also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which when loaded in a computer system is able to carry out these methods. Computer program in the present context means any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following: a) conversion to another language, code or notation; b) reproduction in a different material form.

While the present invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the present invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present invention without departing from its scope. Therefore, it is intended that the present invention not be limited to the particular embodiment disclosed, but that the present invention will include all embodiments falling within the scope of the appended claims.

8

What is claimed is:

1. A method comprising:
determining, by a cable modem termination system (CMTS), for each cable modem served by said CMTS, a corresponding signal-to-noise ratio (SNR) related metric;

assigning, by said CMTS, each cable modem among a plurality of service groups based on a respective corresponding SNR-related metric;

generating, by said CMTS for each one of said plurality of service groups, a composite SNR-related metric based at least in part on a worst-case SNR profile of said SNR-related metrics corresponding to said one of said plurality of service groups;

selecting, by said CMTS, one or more physical layer communication parameter to be used for communicating with said one of said plurality of service groups based on said composite SNR-related metric; and

communicating, by said CMTS, with one or more cable modems corresponding to said one of said plurality of service groups using said selected one or more physical layer communication parameter.

2. The method of claim 1, wherein said one or more physical layer communication parameter includes one or more of: transmit power, receive sensitivity, timeslot duration, modulation type, modulation order, forward error correction (FEC) type, and FEC code rate.

3. The method of claim 1, wherein said CMTS uses orthogonal frequency division multiplexing (OFDM) over a plurality of subcarriers for said communicating.

4. The method of claim 3, comprising selecting, by said CMTS, said one or more physical layer communication parameter on a per-OFDM-subcarrier basis.

5. The method of claim 4, wherein said one or more physical layer communication parameter includes one or both of: which of said OFDM subcarriers to use for transmission to said CMTS, and which of said OFDM subcarriers to use for reception of information from said CMTS.

6. The method of claim 1, wherein:
said plurality of service groups comprises a first service group and a second service group;
said first service group has a first composite SNR versus frequency profile, said second service group has a second composite SNR versus frequency profile, and a particular cable modem has a particular SNR versus frequency profile; and
said assigning said each cable modem among said plurality of service groups comprises, for the particular cable modem:

assigning said particular cable modem to said first service group if said particular SNR versus frequency profile is more similar to said first composite SNR versus frequency profile than to said second composite SNR versus frequency profile; and
assigning said particular cable modem to said second service group if said particular SNR versus frequency profile is more similar to said second composite SNR versus frequency profile than to said first composite SNR versus frequency profile.

7. The method of claim 1, comprising assigning said cable modems among said plurality of service groups based on respective distances between said CMTS and said cable modems.

8. The method of claim 1, comprising assigning any particular one of said cable modems to one of said plurality

US 10,135,682 B2

9

of service groups based on which one or more of a plurality of branch amplifiers are upstream of said one of said plurality of cable modems.

9. The method of claim 1, wherein said determining said plurality of SNR-related metrics comprises:

transmitting a probe message to each cable modem, said probe message comprising instructions for measuring a metric and reporting said measured metric back to said CMTS; and

receiving a metric reporting message from each cable 10 modem.

10. A system comprising:

circuitry for use in a cable modem termination system (CMTS), said circuitry comprising a network interface and a processor wherein:

said processor is configured to determine, for each cable modem served by said CMTS, a corresponding signal-to-noise ratio (SNR) related metric;

said processor is configured to assign each of said cable 20 modems among a plurality of service groups based on a respective corresponding SNR-related metric;

said processor is configured to generate, for each one of said plurality of service groups, a composite SNR-related metric based at least in part on a worst-case SNR profile of said SNR-related metrics corresponding 25 to said one of said plurality of service groups;

said processor is configured to select one or more physical layer communication parameter to be used for communicating with said one of said plurality of service groups based on said composite SNR-related metric; and

said network interface is configured to communicate with one or more cable modems corresponding to said one of said plurality of service groups using the one or more selected physical layer communication parameter.

11. The system of claim 10, wherein said one or more physical layer communication parameter includes one or more of: transmit power, receive sensitivity, timeslot duration, modulation type, modulation order, forward error correction (FEC) type, and FEC code rate.

12. The system of claim 10, wherein said network interface and said cable modems are configured to communicate using orthogonal frequency division multiplexing (OFDM) over a plurality of subcarriers.

13. The system of claim 12, wherein said network interface is configured such that at least one of said one or more

10

physical layer communication parameters are configurable on a per-OFDM-subcarrier basis.

14. The system of claim 12, wherein said one or more physical layer communication parameter includes one or both of: which of said OFDM subcarriers to use for transmission to said CMTS, and which of said OFDM subcarriers to use for reception of information from said CMTS.

15. The system of claim 10, wherein:

said plurality of service groups comprises a first service group and a second service group;

said first service group has a first composite SNR versus frequency profile, said second service group has a second composite SNR versus frequency profile, and a particular cable modem has a particular SNR versus frequency profile;

said assignment of said each cable modem among said plurality of service groups comprises, for the particular cable modem:

assignment of said particular cable modem to said first service group if said particular SNR versus frequency profile is more similar to said first composite SNR versus frequency profile than to said second composite SNR versus frequency profile; and assignment of said particular cable modem to said second service group if said particular SNR versus frequency profile is more similar to said second composite SNR versus frequency profile than to said first composite SNR versus frequency profile.

16. The system of claim 10, wherein said processor is configured to assign said cable modems among said plurality of service groups based on respective distances between said CMTS and said cable modems.

17. The system of claim 10, wherein said processor is configured to assign each of said cable modems among said plurality of service groups based on one or more branch amplifier that serves said each of said cable modems.

18. The system of claim 10, wherein said determination of said plurality of SNR-related metrics comprises:

transmission, via said network interface, of a probe message to each cable modem, said probe message comprising instructions for measuring a metric and reporting said measured metric back to said CMTS; and reception, via said network interface of said CMTS, of a metric reporting message from each cable modem.

* * * * *